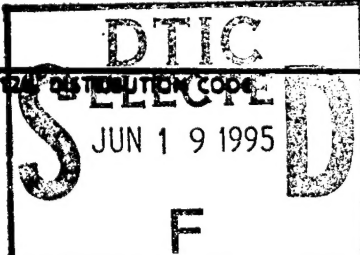


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13. ABSTRACT (Maximum 200 words)  This report summarizes the research accomplishments under contract #AFOSR-91-0353 at Princeton University. It has three parts:  (1) submillimeter wave response of laterally patterned quantum structures,  (2) energy structure of two-dimensional holes, and  (3) detection of the composite fermions in fractional quantum Hall effect.  DTIC QUALITY INSPECTED 8				
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## I. INTRODUCTION

This is a final report on the research carried out at Princeton University under the Air Force Office of Scientific Research Contract No. #91-0353. Accomplishments in these different areas are summarized; they are:

(1) Submillimeter wave response of laterally patterned two-dimensional (2D) electron structures, in which the 2D electron gas is quantum confined into one-dimensional quantum wires;

(2) Energy structure of 2D holes determined by quantum transport and cyclotron absorption in the far infrared, and

(3) Detection of the composite fermions in fractional quantum Hall effect (FQHE).

## II. SUMMARY OF ACCOMPLISHMENTS

### II.1 Submillimeter wave response of quantum wire arrays and electron grids

We find that the resonant absorption of a quantum wire array cannot be accounted for by the widely accepted single quantum wire model of one-dimensional (1D) subband transition plus a depolarization shift. The influence of neighboring wires are important and can change the resonant energy by a factor of 2 or 3. The effect of inter-wire coupling can be quite simply described by a 1D harmonic potential taking into account of the charge distribution of the system. This model also accounts for the large discrepancies between experiment and theory already in the literature.

We also fabricated a two-dimensional (2D) electron grid in the high mobility GaAs/Al<sub>0.35</sub>Ga<sub>0.65</sub>As heterostructure and observed, in the magneto-optical absorption, new resonances and an anomalous dispersion in antidots in a high density InGaAs/AlInAs heterostructure. We have studied their dependencies on the 2D electron density and demonstrate their plasma origin. The anomaly in magnetic field dependence is explained by the mixing of cyclotron resonance and edge magnetoplasma modes in this 2D electron microstructure. A theory for the magnetoplasmas of 2D electron grid, or antidot, structure was developed using a variational Wigner-Seitz model to quantitatively account the experimental results.

### II.2 Energy structure of 2D holes.

#### (a.) Crystal field restraining of hole spin orientations.

A charge carrier in a semiconductor has spin and, in the absence of a magnetic field H, the spin is free to point in any direction. The application of H selects the special di-

rection and the Zeeman energy is the energy it takes to align the spin with  $H$ . We discover through our quantum transport studies that the spin of the two-dimensional holes in (001) GaAs/InGaAs strained-layer structures can only point in the directions perpendicular to the surface.  $H$  parallel to the surface cannot align the spin and the Zeeman energy is given totally by the perpendicular component of  $H$ . In spin resonant language, the  $g$ -factor is infinitely anisotropic and this extreme  $g$ -factor anisotropy is a direct consequence of the biaxial in-plane strain, giving rise to a crystal field that restrains the spin orientation of the carriers to the surface normal directions through spin-orbit coupling.

**(b.) Direct measure of in-plane dispersion of holes in AlAs/InGaAs/AlAs strained layer quantum wells by resonant magneto-tunneling**

In our previous resonant tunneling work, we find that the application of a magnetic field  $H$  parallel to the junction shifts the resonant peaks and the shift can be understood quantitatively in terms of the following physical picture: in tunneling through the emitter barrier, the charge carrier acquires an in-plane momentum  $\Delta\kappa$  directly related to  $H$  ( $\Delta\kappa = eH\langle z \rangle / \hbar$ , where  $\langle z \rangle$  is the tunneling distance). Since the peak position is related to the subband energy, the measurement measures directly the in-plane dispersion of the 2D carriers in the quantum well. We have applied this technique and measured the dispersion of the 2D holes in the strained-layer quantum well structure of AlAs/InGaAs/AlAs.

**(c.) Cyclotron resonance line splitting of 2D holes - - a longstanding problem finds a simple solution**

Anomalous line splitting has been seen in far infrared cyclotron resonance of 2D carriers in GaAs/AlGaAs heterostructures as well as Si-MOSFET's. While the anomaly in the electron case remains a challenging problem and is probably a manifestation of some new many-body physics, the hole case is now solved and it is due to crossing of Landau levels associated with the heavy-hole and light-hole subbands. We solved the problem by carrying out subband resonance measurements on the same sample in the same run and demonstrating that the cyclotron resonance splitting occurs at the energy, and has the density dependence, expected from the crossing.

**II.3 Experimental Evidence for New Particles in the Fractional Quantum Hall Effect**

We have determined the energy gaps of both prominent sequences of fractional quantum Hall effect (FQHE) states at filling factor  $\nu = p/(2pz \pm 1)$  around Landau level filling factor  $\nu = 1/2$ . The gaps increase linearly with  $\Delta B$ , the deviation of the magnetic field from half filling. Therefore, the data are indistinguishable from Shubnikov-de Haas oscillations of particles of charge  $e$ , *effective* mass  $m^*$ , and lifetime broadening  $\Gamma$  exposed to an effective magnetic field  $\Delta B$ . Our findings are remarkably consistent with recent proposals of compos-

ite particles in the FQHE and the existence of a Fermi surface at even-denominator fillings.

By analyzing the magneto-resistance due to these higher-order FQHE around  $\nu=1/2$  Landau level filling factor within the standard framework of Shubnikov-deHaas oscillations adopting  $\nu=1/2$  as the new origin for a effective magnetic field  $B_{eff}$ , and find it readily applicable, we deduce *ad hoc* effective masses, and scattering rates from our analysis. The masses are approximately constant and exceed the electron mass in GaAs by about a factor of 10. Our successful analysis of the FQHE features, in terms of this conventional tool for electron magneto-transport, further strengthens the case for the existence of exotic new particles in the FQHE.

### III. PUBLICATION OF WORK SUPPORTED BY CONTRACT

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#### IV. PERSONNEL SUPPORTED BY CONTRACT

1. Graduate student -  
Yang Zhao, Ph.D., Dept. of Electrical Engineering, now with Analog Devices, Wilmington, MA.
2. Post doc -  
Rui R. Du, Ph.D. from Department of Physics, University of Illinois, now assistant professor, Physics Department, University of Utah.